An Encrypted Traffic Classification Model Based on Improved Dense Network and Bidirectional Gated Recurrent Unit

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Abstract

Aiming at **the problems of incomplete data feature extraction and long training time** in the current encrypted traffic classification model, an improved model is proposed.

Using one-dimensional convolution and LeakyReLU in the dense connection part--improve the learning ability; extract the spatial features; reduce the training time.

Using a bidirectional gated recurrent unit(BiGRU)--extract the complete time series features.

Compared with the existing models, our improved model performs better **with the accuracy of 96.4%, precision of 96.8%, and recall of 96.6%.**

Introduction

The existing models for encrypted network traffic classification still face the following issues:

1) Most models use two-dimensional convolutional neural networks, which require **a large number of training parameters** and suffer from **poor training time performance**;

2) Single neural network models have difficulty **comprehensively extracting traffic features**.

Methods

- A. Design of the Improved Model

The improved model uses an enhanced densely connected network to extract spatial features. To address the limitation of convolutional neural networks in extracting temporal features, it incorporates a bidirectional Gated Recurrent Unit (BiGRU). Finally, the features extracted by these two components are fused and used for classification.

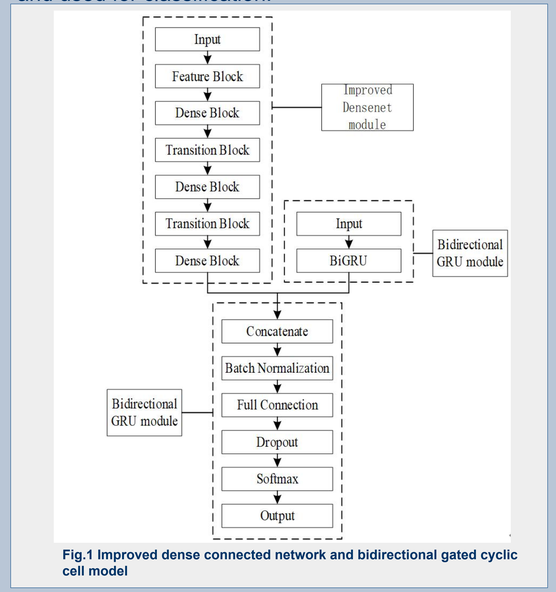

Fig.1 Improved dense connected network and bidirectional gated cyclic cell model

- B. Feature Fusion Module

The Feature Fusion Module includes the following layers: Concatenate Layer, Batch Normalization Layer, Fully Connected Layer, Dropout Layer and Output Layer. The functions and parameter settings for each layer are listed in Table 1.

Table 1. Feature fusion module network level

Layers	Network Structure
Concatenate Layer	Concatenate
Batch Normalization Layer	Batch_Normalization
Fully Connected Layer	Dense, 64, Leaky ReLU
Dropout Layer	Dropout 0.5
Output Layer	Dense, 4, Softmax

Results

- A. Effectiveness of the Feature Fusion Module

The models using only Densenet or BiGRU have significant performance gaps in loss value and accuracy compared to the proposed integrated model.

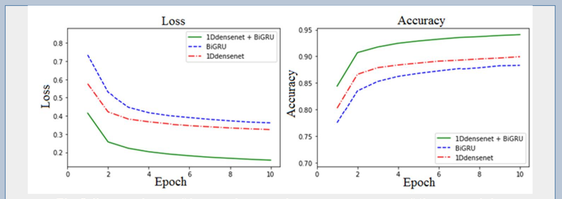

Fig.2 Comparison of loss values and accuracy curves of three models

- B. Classification Performance Comparison

Compared to the models in other studies, the proposed model in this paper shows improvements in all evaluation indicators, achieving relatively better classification results.

Table 2. Comparison of evaluation indicators with existing models

Models	Accuracy	Precision	Recall	F1 score
1DDensenet+BiGRU	96.4%	96.8%	96.6%	0.967
SAE[11]	87.6%	87.2%	88.1%	0.874
SPCaps[11]	95.7%	96.8%	96.0%	0.964
LogisticRegression[12]	94.6%	89.0%	95.2%	0.920
DarknetSec[13]	92.2%	92.4%	91.8%	0.921

Conclusions

By combining these features for comprehensive classification, the model achieves significant improvements in classification accuracy, precision, and recall. Compared to single classification models, the hybrid network traffic classification model has certain advantages due to its ability to extract more comprehensive features.

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